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# Occupational Health in Ontario

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*An Evaluation of Routine Health Records of PGDN-Exposed Workers*

*What Epidemiology Cannot Do in Occupational Health Research*

*Cashier Workstation Ergonomics*

*Guidelines for Examining Physicians on Surveillance of Isocyanate-Exposed Workers*

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# An Evaluation of Routine Health Records of PGDN-Exposed Workers

## Summary

*For 10 years employees exposed to propylene glycol dinitrate (PGDN) in the servicing of torpedoes have been submitted to routine annual health examinations not specific to PGDN. A study was undertaken to determine if long-term health effects could be detected from data recorded in the personal health records of 63 randomly chosen ships' crews. Results showed that family, past medical history and lifestyle risk factors were poorly recorded. In addition, since adverse health effects attributed to PGDN were not sought, the long-term health effects due to PGDN exposure could not be assessed. The authors recommend that annual examination be made more specific to the hazard to which employees are exposed, and question the role of routine tests such as haemoglobin, chest X-ray and EKG.*

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Propylene glycol dinitrate (PGDN) is the main constituent of Otto Fuel II, a liquid torpedo propellant. PGDN is a nitrated ester and chemically similar to ethylene glycol dinitrate, a component of dynamite. Nitrated esters have been found to produce vasodilatation, headache, nasal congestion, eye irritation, dizziness, dyspnoea, nausea, hypotension, vasomotor collapse and unconsciousness.[1]

Because of its known acute effects, PGDN is deemed a hazardous substance for occupational exposures. In a human study with volunteers,[2] subjects were exposed to varying levels of PGDN vapour for short periods of time. They developed headaches at 0.2 ppm, impairment in performing simple tests of co-ordination at 0.5 ppm and eye irritation at 1.5 ppm. Based on this study, and on animal studies, the ACGIH TLV has been set at 0.05 ppm.[3,4,5] A study by Horvath *et al*[6] found that PGDN could cause acute, subclinical neurologic alterations as detected by occulomotor function tests. These effects were judged not to be harmful. It is recommended that for the protection of workers, appropriate ventilation systems, protective clothing and monitors for the detection and measurement of PGDN are necessary.[1]

The long-term health effects of low dose exposures to PGDN are not known. Therefore, a study was initiated to determine if adverse health effects to workers exposed to PGDN could be determined using routinely collected health examination data. A secondary concern of the study was to ascertain the usefulness of routinely collected health information in general and, in particular, to advise the Medical Services regional office on an appropriate health monitoring program for PGDN-exposed employees.

## Methods

In Dartmouth, Nova Scotia, a number of civilian personnel have been exposed to Otto Fuel II in the maintenance and servicing of torpedoes. These employees are subjected to a routine annual medical examination by a physician as well as selected tests

including chest X-ray and EKG. This examination is similar for all federal employees in Canada who are potentially exposed to hazardous substances. The purpose of this medical surveillance is to ascertain adverse health effects due to working conditions or exposures to harmful substances as well as to determine fitness for work. The examination performed was not modified to be specific to exposure to PGDN. The results were recorded on standard forms, which were placed in the individual employee's personal file.

The study population consisted of those personnel who were potentially exposed to Otto Fuel II at the time of the study. For a comparison group, ships' crews were selected since they were also subjected to annual medical examinations because of their lack of access to medical facilities when they are at sea; they are not known to be exposed to toxic chemical substances.

For each Otto Fuel worker, a match was drawn from the list of ships' crews based on age and the number of medical examinations attended. Subsequently, each Otto Fuel worker or his supervisor was asked to complete a questionnaire estimating the number of hours that an employee had been exposed to Otto Fuel during each year from 1972 to 1981 inclusive. After this was done, it was noted that five names from personnel records did not match the list from the exposure questionnaire. Therefore, those five names were withdrawn. Thus the final number consisted of 63 Otto Fuel workers and 68 ships' crews.

The medical files of each man were reviewed, and data were abstracted onto a coding sheet. Data were only available for 1972 to 1981 as the medical records were only retained for 10 years. All the data were keypunched and analysed by means of the SAS computer package.

## Results

Table 1 shows the exposure categories and worksite of the Otto Fuel workers. Since the nature of exposures was so different, it was not possible to quantitatively estimate the exposure dosage, nor to place exposure levels in a continuum. However, it was possible to group the workers into discrete exposure categories based on the number of hours per week of potential exposure. Group 1 consisted of 13 men who, because they worked with Otto Fuel infrequently, had a low level of exposure. Group 2 consisted of 18 workers who worked more regularly with Otto Fuel, and Group 3

consisted of 21 men who had regular, continuous exposure to PGDN. Workers in Groups 1-3 were exposed to PGDN at or below the pre-1980 TLV of 0.2 ppm as established by PGDN monitors.

**Table 1**

**Exposure Groups and Number of Years of Exposure, by Building**

| | | Number of Employees | Building | Average Number of Years of Exposure Mean ± S.D. |
|---|---|---|---|---|
| Group 1. | Low Exposure | 13 | 2 | 8.8 ± 9.0 |
| Group 2. | Intermediate Exposure | 18 | 2 | 7.8 ± 12.3 |
| Group 3. | Continuous Exposure | 11 | 2 | 7.9 ± 8.9 |
| Group 4. | High Intermittent Exposure | 21 | 1 | 4.7 ± 11.9 |

Group 4 consisted of 21 men who worked in Building 1. These men had a high, but intermittent, exposure to Otto Fuel as their job was to fuel and defuel the torpedoes. However, because of the high air levels of PGDN, they wore protective clothing and self-contained breathing apparatus. The number of years of exposure was not different for workers in Building 2 (Groups 1-3), but was lower for the men in Building 1.

Although an annual examination was required for each worker, it was found that, frequently, the examination was not conducted. The number of men who had an examination each year is seen in Table 2. The mean number of examinations was 5.7 for the ships' crews and 5.6 for the Otto Fuel workers. The Otto Fuel workers were better attenders in recent years, but it is not known whether this was because of a recall system to ensure that workers reported for their annual examinations or whether this reflects an increased interest on the part of Otto Fuel workers in their own health.

**Table 2**

**Number of Annual Examinations**

| Year | Ships' Crews | Otto Fuel Workers |
|---|---|---|
| 1981 | 35 | 50 |
| 1980 | 44 | 55 |
| 1979 | 49 | 40 |
| 1978 | 54 | 55 |
| 1977 | 42 | 55 |
| 1976 | 42 | 40 |
| 1975 | 44 | 32 |
| 1974 | 36 | 16 |
| 1973 | 33 | 8 |
| 1972 | 11 | 10 |
| **Total** | **390** | **361** |
| Mean Number of Examinations per Employee | 5.7 | 5.6 |

It was thought that the medical files would contain information relating to the alleged symptoms and signs that were being attributed to PGDN. This proved not to be the case. Table 3 lists the data sought and whether or not they were available.

**Table 3**

**Availability of Useful Data**

| Data Sought | Availability |
|---|---|
| Date of Birth | available |
| Years of employment at Bedford Ammunition Depot or Halifax Naval Dockyard | not available |
| Jobs held in past | not available |
| Present job | available |
| Building in which employee worked | available |

| Medical History | |
|---|---|
| Smoking history | greater than 25 per day — yes or no |
| Alcohol consumption | greater than 6 oz per day — yes or no |
| Previous illnesses | inconsistently recorded |
| Prescription drug use | inconsistently recorded |
| Family history | inconsistently recorded |

| Symptoms | |
|---|---|
| Headaches (number, location, duration, nature) | headaches — yes or no |
| Nasal congestion | not asked |
| Eye irritation | not asked |
| Dizziness | not asked |
| Dyspnoea | not asked as a separate question |
| Nausea | not asked |
| Skin irritation | not asked |
| Chest pain | yes or no |

| Physical findings | |
|---|---|
| Weight | available |
| Pulse rate | available |
| Visual acuity | not done |
| Conjunctivitis | not sought specifically |
| Skin rash or discolouration | not sought specifically |
| Urinalysis | available |
| Pulmonary function tests | not done |
| Haemoglobin | available |
| Blood pressure | available |
| EKG | available |
| Methemoglobin | not done |
| Chest X-ray | available |

Of the symptoms associated with PGDN exposure, questions about headache, dyspnoea and chest pain were included on the standard questionnaire. However,

no details about these symptoms were requested, only whether or not they were present. With regard to physical findings, weight, pulse rate and blood pressures were routinely recorded. Signs specific to Otto Fuel overexposure — conjunctivitis, nasal congestion or skin discolouration — were not specifically sought. Laboratory tests performed included urinalysis, haemoglobin, EKG and chest X-ray. Methemoglobin estimations and pulmonary function tests were not performed.

The present and past medical history was found to be poorly documented. For example, there were only 13 men among the ships' crews and seven among the Otto Fuel workers who reported smoking more than 25 cigarettes per day. Even if reporting had been good, the data would have been of virtually no use in ascertaining health status since the question 'Do you smoke more than 25 cigarettes per day?' on the standardized form excludes many persons who smoke significant numbers of cigarettes. Similar criticism can be made for questions on alcohol usage. Family medical history data were also poorly and inconsistently recorded.

The overall 10-year mean pulse rate and systolic and diastolic blood pressures were very similar for the two groups (Table 4). Examining the data by year, there was a small rise in mean blood pressures with calendar year, which was seen in both groups. There were no statistically significant differences between the two groups with regard to yearly blood pressure or pulse rates.

**Table 4** **Crude Mean Weight, Pulse Rate, Systolic Blood Pressure, Diastolic Blood Pressure of Ships' Crews and Otto Fuel Workers**

| | Ships' Crews | Otto Fuel Workers |
|---|---|---|
| | Mean ± S.D. | Mean ± S.D. |
| Crude Mean Weight (kg) | 85.6 ± 5.5 | 81.1 ± 4.4 |
| Crude Mean Pulse Rate (per minute) | 73.5 ± 4.0 | 73.3 ± 4.5 |
| Crude Mean Systolic Blood Pressure (mm Hg) | 124.8 ± 7.9 | 125.3 ± 5.7 |
| Crude Mean Diastolic Blood Pressure (mm Hg) | 77.7 ± 4.8 | 77.3 ± 3.7 |

Since the number of men differed in each year, a transformation of the data was carried out to construct a summary variable so that the 10-year data for each man could be used. A mean value for each man was determined by summing the values for a given variable and dividing by the number of examinations he attended. This was referred to as the 'average value for each man.' These average values were then summed for the two groups and divided by the number of men in each group. This summary value is referred to as the 'mean of the average values for each man.' Table 5 shows that there were no differences between the two groups with respect to height, pulse rate and blood pressure. Ships' crews were heavier (mean weight 85 kg) than the Otto Fuel workers (80.9 kg).

**Table 5** **Mean of Average Values for Each Man for Continuous Variables**

| | Ships' Crews Mean ± S.E. | Otto Fuel Workers Mean ± S.E. | Significance (t-test) |
|---|---|---|---|
| Number of Employees | 68 | 63 | |
| Weight (kg) | 85.0 ± 1.5 | 80.9 ± 1.3 | $p < .05$ |
| Height (cm) | 176.0 ± 0.7 | 175.8 ± 0.8 | N.S. |
| Bodymass | 27.5 ± 0.5 | 26.2 ± 0.4 | $p < .05$ |
| Pulse Rate | 73.4 ± 0.9 | 73.5 ± 1.1 | N.S. |
| Systolic B.P. | 123.9 ± 1.9 | 125.7 ± 1.5 | N.S. |
| Diastolic B.P. | 77.2 ± 1.2 | 77.7 ± 0.91 | N.S. |
| Age in 1981 (years) | 43.9 ± 1.2 | 43.0 ± 1.2 | N.S. |

Table 6 looks at the 10-year average values for men who were younger or older than 43 years of age. There is a significant difference between the two groups in the blood pressures of the younger workers. Otto Fuel workers had higher blood pressures despite their being of lower weight than the ships' crews. The reverse picture is seen for men over 43 years of age.

With regard to the discrete variables, there were no differences found with regard to dyspnoea and chest pain (Table 7). However, Otto Fuel workers reported headaches in 16 per cent of their total number of examinations. Of the 42 workers in Building 2, 21

reported headaches at least once during the 10-year period. Further analysis showed that there was no relationship between the number of years worked and the frequency of headaches (R=.015), nor between the age of men and the frequency of headaches (R=.116).

**Table 6** **Mean of Average Values for Each Man**

| | Ships' Crews Mean ± S.E. | Otto Fuel Workers Mean ± S.E. | Significance (t-test) |
|---|---|---|---|
| Men Younger Than 43 Years | | | |
| Number of Employees | 29 | 29 | |
| Systolic B.P. | 117.9 ± 1.9 | 123.5 ± 1.5 | $p < .05$ |
| Diastolic B.P. | 73.1 ± 1.2 | 76.3 ± 1.0 | $p < .05$ |
| Bodymass | 27.3 ± 0.6 | 25.8 ± 0.7 | $p < .05$ |
| Weight (kg) | 84.6 ± 2.0 | 79.1 ± 2.1 | $p < .05$ |
| Men 43 Years or Older | | | |
| Number of Employees | 39 | 34 | |
| Systolic B.P. | 128.4 ± 2.8 | 127.7 ± 2.5 | N.S. |
| Diastolic B.P. | 80.4 ± 1.7 | 78.9 ± 1.4 | $p < .05$ |
| Bodymass | 27.6 ± 0.6 | 26.5 ± 0.5 | $p < .05$ |
| Weight (kg) | 85.3 ± 2.2 | 82.5 ± 1.7 | $p < .05$ |

**Table 7** **Percentage of Examinations That Were Positive for Selected Variables**

| | Ships' Crews | Otto Fuel Workers | Building 1 | Building 2 |
|---|---|---|---|---|
| Number of Employees | 68 | 63 | 21 | 42 |
| Headache (%) | 7.3% | 15.8% | 4.5% | 23% |
| Dyspnoea (%) | 1.3% | 2.0% | | |
| Chest Pain (%) | 1.8% | 1.2% | | |

Table 8 gives the results of the laboratory tests in terms of the number of measurements performed and the number of abnormalities detected. An abnormal measurement was taken to be any value that was not recorded in the medical record as normal, regardless of how minor in nature. In fact, the vast majority of these

**Table 8** **Numbers of Clinical Tests and Abnormal Clinical Tests**

| | Ships' Crews | Otto Fuel Workers |
|---|---|---|
| Number of Urinalyses | 385 | 354 |
| Number of Urinalyses per Employee | 5.7 | 5.6 |
| Number of Abnormal Urinalyses | 16 (4.2%) | 6 (1.7%) |
| Number of B.P. Measurements | 376 | 355 |
| Number of B.P. Measurements per Employee | 5.5 | 5.6 |
| Number of B.P. Measurements $>$ 90mm Hg Diastolic | 35 (9.3%) | 20 (5.6%) |
| Number of CXRs | 386 | 354 |
| Number of CXRs per Employee | 5.7 | 5.6 |
| Number of Abnormal CXRs | 2 (0.5%) | 4 (1.2%) |
| Number of EKGs Performed | 108 | 308 |
| Number of EKGs per Employee | 1.6 | 4.9 |
| Number of Abnormal EKGs | 20 (18.5%) | 36 (11.7%) |
| Number of Haemoglobins Performed | 2 | 320 |
| Number of Haemoglobins per Employee | — | 5.1 |
| Number of Haemoglobins $>$ 18g/100 ml and $<$ 11g/100 ml | — | 1 (0.3%) |

so-called positive results were minor abnormalities, for example in the urinalyses, a trace of protein.

There were, on average, 5.7 urinalyses per employee for ships' crews and 5.6 for Otto Fuel workers. Abnormalities in the two groups were detected at 4.2 per cent and 1.7 per cent respectively. For blood pressures, the average number of readings was 5.5 for ships' crews and 5.6 for Otto Fuel workers. Nine per cent of ships' crews had at least one reading of greater than 90 mm Hg compared to six per cent of Otto Fuel workers. Three hundred and eighty-six chest X-rays were carried out on ships' crews and 354 on Otto Fuel workers, but in only about one per cent was any abnormality detected. EKGs numbered 108 for ships' crews and 308 for Otto Fuel workers. There were 19 per cent abnormalities in ships' crews and 12 per cent abnormalities in Otto Fuel workers, with the majority being minor in nature (e.g. non-specific T-wave changes). In the majority of cases there was no systematic mode of follow-up of these employees with regard to abnormal laboratory results.

## Discussion

This study had several limitations imposed on its ability to detect any adverse health effects that might be attributable to working with Otto Fuel. First, there was a lack of suitable medical data for scientific analysis recorded in the personal medical files. Where there were positive historical or physical findings noted, there was usually no indication that they had been followed up. Therefore, it is possible that adverse health effects were not detected because they were not specifically sought due to the use of a standardized form rather than an examination directed specifically at health effects suspected as being attributable to exposure to nitrated esters.

Second, the study only included workers who were employed at the time of the study, and thus they would be under-reporting adverse health effects. It is probable that only the more healthy workers remained; that is, those whose health may have been adversely affected by Otto Fuel either were transferred to other jobs or terminated employment due to ill health. Thus the surveillance may have been more successful at determining fitness to work. However, it was not the purpose of the study to evaluate this.

Third, the statistical power of the study was low due to the small sample size of only 63 workers. There may have been a difference in health between the two groups of workers, but the magnitude of the difference would

need to be large in order for it to be detectable. For example, at an $\alpha$ =.05 and $\beta$=.80, with the sample of 63 workers, we would have to detect a difference in diastolic blood pressure of at least 2.8 mm Hg between the two groups to be significant. The difference found was only 0.5 mm Hg.

The finding of higher blood pressures among the younger Otto Fuel workers compared to the ships' crews is an interesting one, but there is insufficient evidence to attribute this to Otto Fuel. It is possible that the ships' crews had particularly low blood pressures. At any rate, the readings in the Otto Fuel workers were not markedly elevated. This finding of possible blood pressure effects is one that could be further explored in future studies.

There was an increased frequency of headaches among workers in Building 2, and the frequency was not related to age or to length of employment. It is possible that this may be due to exposure to Otto Fuel since it is known that nitrated esters cause headaches in certain individuals. Whether the headaches are a result of poor work practices must also be a topic for future study.

## Conclusion

In conclusion, this study was unable to determine by the use of existing medical records if there were any long-term cardiovascular health effects that might be attributable to working with propylene glycol dinitrate, the main constituent of Otto Fuel II. An increase in headaches due to exposure is likely. Future studies, looking at all workers (past and present) exposed to this substance, will have to be undertaken to determine if there are any long-term adverse health effects due to Otto Fuel II.

Routinely collected health data could be used to indicate whether health problems due to occupational exposure are developing. To make them more useful, the authors recommend that:

1. If an employee is exposed to an agent whose effects on health are known or suspected, the medical enquiry should be directed towards those specific areas, whether to ascertain adverse short- or long-term health effects or to ascertain fitness for work. In Otto Fuel workers close attention should be directed to headaches (nature, location, duration, number, severity, time lost from work), nasal congestion, eye irritation and pulmonary function. Physical signs that may be attributable to Otto Fuel II should be regularly monitored. These signs include evidence of conjunctival irritation, skin discolouration and rhinitis.

2. Information on suspected adverse exposure(s) and/or a general annual work history be collected at the same time as the health monitoring is conducted.

3. Weight, blood pressure, smoking history and prescription drug use should be routinely monitored. At least one height measurement should be available.

4. Care must be taken in selecting screening procedures such as EKG, chest X-ray, haematology, biochemistry, etc. These can be time consuming and disruptive to employees and management, and can be medically unrewarding if used indiscriminately.

5. A follow-up system should be devised and implemented to ensure that, as far as possible, employees attend their scheduled examinations.

6. A mechanism should be put in place whereby detected specific medical problems, such as hypertension, be followed up and treated.

7. Medical records for employees at risk should be indefinitely retained on microfilm.

8. Provision should be made for periodic review of the data.

**Résumé**

Depuis 10 ans, les employés exposés au dinitrate de propylèneglycol (PGDN) dans l'entretien et la réparation des torpilles ont été soumis à des examens médicaux systématiques qui ne s'appliquent pas spécifiquement au PGDN. Une étude a été entreprise dans le but de déterminer si les effects à long terme sur la santé pourraient être détectés à partir des renseignements consignés dans les dossiers médicaux personels de 63 ouvriers travaillant dans des usines de fabrication de torpilles et de 68 membres d'équipages de torpilleurs choisis au hasard. Les résultats ont montré que la famille, les antécédents médicaus et les facteurs de risque attachés au style de vie avaient peu de place dans les dossiers. En outre, du fait que l'on ne recherchait alors aucun effet néfaste attribuable au PGDN, il était impossible d'évaluer les effets à long terme de l'exposition à ce produit. Les auteurs recommandent que les examens médicaux annuels soient plus spécifiquement adaptés aux risques auxquels les employés sont exposés et s'interrogent sur le rôle des analyses systématiques telles que prises de sang, radiographies pulmonaires et ECG.

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# What Epidemiology Cannot Do in Occupational Health Research*

**Summary**

*Epidemiology is defined as the study of the distribution and determinants of disease in populations. Diseases of occupational origin can be so investigated, and the common problem areas are discussed. Examples are given to illustrate proportional mortality, case-control and cohort studies.*

I am glad to have an opportunity of talking about epidemiology, and, as this subject has recently become popular in clinical circles, of discussing what epidemiology cannot do. Some people have regarded it as a new miracle. Epidemiology is, in some ways, very old and, in some ways, it is new. Its essential qualities are that it uses systems of logic that have been known since the days of the Greek philosophers. Systems of logic are based on observation, and then interpretations are made. Essentially, epidemiology deals with groups of people rather than with the individual. But the observations must always be made on the individual.

## A Definition of Epidemiology

There are many definitions of epidemiology, but it is simple and quite adequate to say that epidemiology is the study of the distribution and determinants of disease in human or animal populations. This type of definition has room for most current activities of epidemiologists. There are people who would add to this that such studies are for the purpose of the prevention, surveillance and control of health disorders in populations. And this addition emphasizes the determinants of health that weigh heavily in public health and medicine. It includes health intervention in matters that societies neglect to undertake. A determinant can be any factor or characteristic or other definable entity so long as it brings about change for better or worse in a health condition. During the 19th century there was great emphasis on a study of the biological determinants of disease, while at the present time the emphasis is on chemical and environmental determinants of disease. An epidemic has to do with the clustering of cases of a particular disease or condition. An epidemiologist talks about the existence of more cases than expected. I am not going into the definition of what health is, except to emphasize that it is often

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difficult to determine whether an individual is healthy or not. But we do it all the time, usually by a process of exclusion. I say a person is healthy when I cannot find signs of disease. Perhaps if I go on long enough with increasing numbers of procedures I may find signs of disease, so that the state of health as far as the physician is concerned is a rather relative term.

This is particularly so in occupational health, where, very often, the signs or symptoms of disease are vague and not noticed. To be a good epidemiologist one must be a good clinician. This may be a medical clinician, a dental clinician or a veterinary clinician if one is working with animals. The important thing about epidemiology is that we must make a diagnosis of a disease or condition. The epidemiologist in occupational health cannot talk about disease conditions or diseases that do not exist or the signs and symptoms that he cannot define. One of the big difficulties of occupational health is that many disease situations are vague, and the very earliest signs or symptoms of an industrial toxic effect very often are missed because one does not know what these signs and symptoms are. We should realize that the human body can only react to toxic substances in a limited number of ways, and that is why the occupational physician must be a good internist. Quite obviously, the second phase of epidemiologic work includes laboratory observations of many kinds, and, of course, we need statistical skills to make sense of our observations. Sometimes they make nonsense of our observations. All epidemiologists need not be clinicians, but a substantial proportion of epidemiologists should be clinicians. Many recent advances in clinical epidemiology in this country have come from the McMaster Medical School, and the reason for this, apart from the selection of brilliant people, is that McMaster combines the clinical approach with statistical skills. This is essential for research work in epidemiology.

## Common Problem Areas in Occupational Health

We know that the identification of work-related medical problems depends most importantly on the occupational history. Medical examination findings and laboratory tests may sometimes raise suspicion or help confirm the disease or injuries when related. But, ultimately, it is information from the occupational history that determines whether the given medical problem is work-related. It is difficult to recognize occupational health problems, and part of the difficulty is that so often physicians do not have a clue about working conditions. A good occupational physician should have

worked in a factory or should have visited factories frequently.

What epidemiology cannot do is put into the epidemiologist's head that information which he or she must gather for himself or herself. In the modern industrial situation the physician should have a very detailed knowledge of all chemicals used in the plants concerned, together with a knowledge of their toxicology. This, again, is something that physicians gather personally, and no epidemiology can put those facts into their heads. Toxicology is an area much neglected in our medical education, but there are signs of improvement between Toronto and Guelph. Further progress will be made during the next few years when the federal government institutions are established.

The plant physician should know what is happening in the factory. There should be an intelligence system concerning disease. Does the patient know of other workers in the workplace or in similar jobs elsewhere who are suffering from the same symptoms or illness? We know that workers and their physicians linked the pesticides DBCP (dibromochloropropane) to male sterility, and the catalyst DMAPN (dimethylamino-proprionitrile) to bladder neuropathy by recognizing that similarly exposed workers had the same medical problems. When we talk about non-occupational factors, we usually talk about smoking and alcohol, but we should also discuss soaps, cosmetics and clothes, and we should talk about chemical or psychological exposures. Do patients live near factories and dumps?; does the patient live with someone who brings substances home from work on clothes, shoes or hair? We should realize that virtually any respiratory symptoms can be work-related. This includes occupational asthma and chronic obstructive pulmonary disease. Here, we think of asbestos. While we know that viruses exist and that cigarettes are consumed, and while we hold these agents responsible for respiratory disease, there may be industrial causes, such as phosgene or oxides of nitrogen. Many skin disorders are non-specific in nature, and contact dermatitis, as we know, accounts for about 90 per cent of all work-related skin disease. It does not necessarily have a characteristic appearance. On the other hand, hearing impairment is probably much more common than people imagine. Which machines produce the deafness? I am not going to talk about backaches, except to say that backache is an enormous problem. Cancers, as we know, may be caused by work exposure. Each year, more occupational carcinogens are discovered. We should remember that initial evidence in

the workplace about noxious substances comes more often from the reports of individual clinicians than from large-scale epidemiological studies. It is the good doctor who makes the observation, and only after that can the epidemiologic study be done. We next look at exacerbation of coronary artery disease symptoms. This may be due to an occupational cause, exposure to stress and to carbon monoxide in the workplace. While it is easy to ascribe liver disease to alcohol or viral hepatitis, we must not forget hepatoxins from an industrial cause. Neuropsychiatric problems may have an industrial origin. More than 100 chemicals, including virtually all solvents, can cause central nervous system depression. Several neurotoxins, including arsenic, lead, mercury and methyl n-butyl ketone can produce peripheral neuropathy. Carbon disulphide exposure can cause psychotic symptoms.

In trying to determine the suspect substance, one should use a systematic method. When we have a list of all the chemicals used in a factory operation, we should start by asking patients whether they know which chemicals make them sick. If we go into the magnitude of the exposure, we should also consider whether the patient became sick when the new chemical was introduced into the environment or whether the illness came later. We should also know a great deal about the toxicology of suspect materials. When our suspicions are aroused, we can get computer searches of the literature and so on done through Medline and other computer aids.

Now let us review some examples of problem-solving epidemiology. The first interesting investigation we will discuss is the matter of palpitations among pathologists. While driving to a vacation retreat a 28-year-old junior pathologist suffered a fatal cardiac arrest. In discussing his untimely death amongst themselves, the other pathology residents discovered that some of them had experienced palpitations severe enough to seek medical care. A hospital epidemiologist recognized that the number of residents experiencing these symptoms was unusual for people of their age, and he began an epidemiological investigation. It was indicated that none of the first-year residents had experienced palpitations, but all second- and third-year residents had. The testing of the work environment showed that the only difference between the first and subsequent years in the pathology and residency program was the absence of the surgical pathology rotation in the first year. Obviously, what was called for under the circumstances was a study of another hospital department with similar types of residents, and the Department of Radiology

was chosen. The incidence of palpitations both before and after employment was studied. It was found that significantly more people in the pathology rotation had palpitations. The offending agents were found to be aerosol preparations, Fluorocarbons 22 and 12. The questionnaire used was designed to discuss smoking, and coffee and alcohol consumption as well. Here we have the simple start of many epidemiological clinical investigations in the general field of occupational disease. The interesting point about this, of course, is that the occupational disease work took place in a hospital, and it is noteworthy that, until relatively recently, hospitals have not been particularly interested in occupational diseases because the assumption has been that occupational diseases don't exist in hospitals. Of course they do.

The second example that we will quote is that of fluorocarbon flu. Early one morning a 42-year-old manager of a textile mill that produced imitation crushed velvet complained of chest discomfort and weakness. His physician suspected myocardial infarction because of an abnormal ECG and elevated cardiac enzymes. The manager subsequently learned that a 24-year-old supervisor had had three short flu-like episodes at just about the same time, with weakness, chest discomfort, cough, wheezing and fever. Other workers were discovered who had similar symptoms. The manager then requested an investigation. What happened next is most important. The occupational physician visited the factory. He found that the operation used a polytetrafluoroethylene compound. Exposure to this compound has been associated with flu-like symptoms, which occur when the fluorocarbon is heated to temperatures over 300°C, which converts the polymer to a hazardous, but, as yet, unidentified substance. The production process at the textile plant had temperatures limited to 165°C.

A listing was then made of all the employees in the area where the polymer was used. Selected characteristics were age, sex, duration of employment, health complaints, time of onset and smoking history. It was found that all the people with symptoms of this syndrome were cigarette smokers. We know that the combustion zone of a cigarette reaches 875°C, and this is more than enough to convert the fluorocarbon polymer to the poisonous fumes. Cigarette smoking near the suspected work area was eliminated, and no more episodes of this illness occurred. What is illustrated is that the physician must be on the ball and should know what is happening in the factory. This problem was solved because the physician was a good clinician.

## Planned Epidemiological Studies

In this type of setting it is obviously impossible to do clinical trials on people by using suspected poisons as the agents. This is definitely not allowed, for obvious reasons. But we can do animal tests, which often are difficult to interpret. Toxicology is a complicated subject.

In occupational medicine the following research plans are commonly undertaken. I will discuss cohort studies and case control studies, and also a simple proportional mortality study based on death certificates of workers in a particular industry or industrial process.

### 1. Proportional Mortality Study — Clues in a Cancer Cluster

Four fatal cases of angiosarcoma of the liver prompted a proportional mortality study of diseased workers in two plants processing or producing vinyl chloride. Death certificates were available in company records on all individuals who died while employed or while on pension, but no information was available on workers who left work before retirement. For 161 deceased workers identified by death certificates, causes of death were tabulated, and compared with expected causes of death, based on age-specific causes of death for U.S. white males (Table 1). Noted were striking excesses in the proportion of deaths from liver and biliary tract cancer and also from brain and lung cancer.

A potential problem with proportional mortality studies is that a high ratio of observed to expected deaths may be due to an excess of one cause of death or a deficit of another. But in Table 1 the frequencies of the other major causes of death are close to expected, so it appears that the excess of cancer is real. Two advantages of this type of study are that it is quick and relatively easy to perform; positive results can then be confirmed by additional studies. When this study was followed up by studies using standardized mortality ratios and case-control techniques, the large excess in liver cancer and the smaller excesses in brain and lung cancer among these workers were confirmed.

The basic information needed to perform a study using either a proportional or a standardized mortality ratio is the date of birth, sex, race, date of hire, job history, date of termination or death, and death certificate report of underlying cause of death.

This simple type of investigation is then followed by many other investigations, such as a case-control study, e.g. cohort investigation.

**Table 1** **Observed and Expected Deaths in Vinyl Chloride Workers**

| Cause of Death | Number of Deaths | | Ratio Observed/ Expected |
|---|---|---|---|
| | Observed | Expected* | |
| All causes | 161 | 161.0 | 1.0 |
| All cancer | 41 | 27.9 | 1.5 |
| Digestive | 13 | 8.3 | 1.6 |
| Liver and biliary tract | 8 | 0.7 | 11.4 |
| Lung | 13 | 7.9 | 1.6 |
| Brain | 5 | 1.2 | 4.2 |
| Lymphatic and haematopoietic | 5 | 3.4 | 1.5 |
| Other | 5 | 7.1 | 0.7 |
| CNS vascular | 8 | 9.5 | 0.8 |
| Circulatory | 66 | 68.5 | 1.0 |
| External | 22 | 24.5 | 0.9 |
| Suicide | 10 | 5.3 | 1.9 |
| All other | 24 | 30.5 | 0.8 |

**Source:** *R.R. Monson, J.M. Peters and M.N. Johnson. Proportional mortality among vinyl chloride workers.* Environ. Health Perspect. *11:75, 1975.*
**Expected numbers based on age-time-cause-specific proportional mortality ratios for U.S. white males.*

## 2. Case Control Studies

The case-control study identifies individuals by the presence of disease or symptoms (Figure 1), and then examines for past or current exposures. This kind of study is generally selected when the health effect being measured is so infrequent that studying any specific population would identify very few cases. For example, if we want to use the case-control approach to determine whether there is a relationship between development of leukemia and exposure to benzene, we would begin by selecting a group of persons with leukemia and a group without leukemia. We would then interview both groups about previous exposure to benzene.

*Example: Tumours in Transportation Workers*

Discovery of new occupational carcinogen, bischloromethylether (BCME), was accompanied by the unusual finding that a less common lung cancer cell type — oat cell or small cell carcinoma — was almost

always diagnosed in the affected workers. This finding suggested that examining each cell type of lung cancer may contribute further to our understanding of the disease. Oat cell carcinoma of the lung in males was selected for study, and 91 cases were identified in a tumour registry. In order to maximize the number of employed persons in the study group, only males under age 60 were selected.

From the same tumour registry, patients with central nervous system cancer were selected as 'control' subjects; at the time of the study, central nervous system tumours had not been associated with work environments. Each case was matched to a control of the same hospital and same 10-year age group. All patients were white males. Family members were then contacted to provide smoking and work histories for cases and controls. Data analysis revealed that transportation equipment operatives were more frequent in the case population than in the control population. Furthermore, their mean age at diagnosis (46 years) was lower than that of their matched controls (50 years). No significant difference in smoking history was found between cases and controls. A similar difference was seen for labourers, but when specific job titles within this group were examined, no common exposures were evident. This suggestive association between transportation work and oat cell carcinoma of the lung was strengthened by another tumour registry study; it is currently being investigated further.

*Case-control studies have three inherent problems*

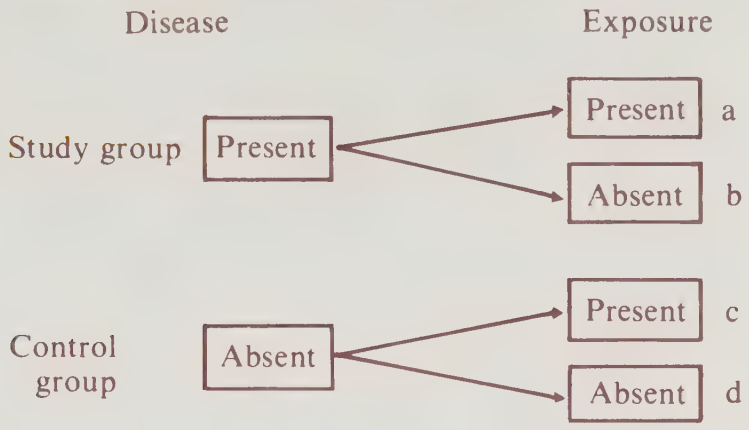
Since exposure data are collected retrospectively, sources of data may be limited; results are dependent on the recall of the individual patients and controls and may be influenced by interviewer bias.

Comparison must be based on exposure data from an appropriately chosen control group. Controls should resemble cases closely in demographic factors to decrease the number of confounding variables, but overmatching can also be a problem. Often multiple control groups are used.

Since the total number of people exposed to the hypothesized risk factor is not known, true incidence rates cannot be determined from case-control studies.

Case control studies start with a disease and go back to exposures. Cohort studies start with an exposure and go forward to diseases.

**Figure 1** **Design of Case-Control Study**




$$\text{Exposure ratio for diseased} = \frac{a}{a + b}$$

$$\text{for nondiseased} = \frac{c}{c + d}$$

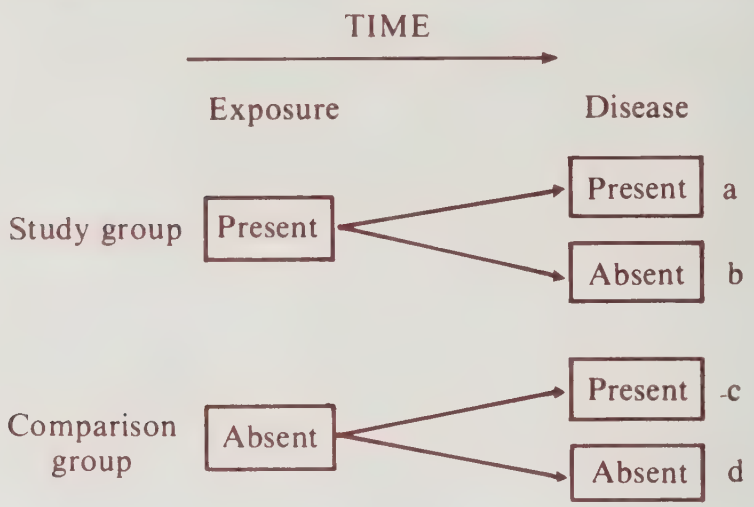
$$\text{Relative exposure ratio*} = \frac{\frac{a}{a + b}}{\frac{c}{c + d}}$$

*Note that if the disease being considered is rare (e.g., less than 5%) then the denominators for each ratio become "b" and "d" and the relative odds = ad/bc.

## 3. Cohort Studies

The cohort study identifies individuals by some common factor, such as exposure prior to the development of disease, and then determines if that factor leads to an adverse effect (Figure 2).

**Figure 2** **Design of Cohort Study**




$$\text{Disease rate for exposed} = \frac{a}{a+b}$$

$$\text{for nonexposed} = \frac{c}{c+d}$$

$$\text{Relative risk} = \frac{\frac{a}{a+b}}{\frac{c}{c+d}}$$

If we wish to examine the relationship between benzene exposure and leukemia in a cohort study, we could examine a population of workers, some of whom are exposed to benzene. We could follow them over time and determine whether leukemia occurs with greater frequency in the group exposed to benzene compared with the group not exposed. Incidentally, this is a vigorous sort of clinical trial that would be unethical in this instance, but it does illustrate my point in designing a cohort study. We could substitute the use of a certain hair dye, or any other chemical substance, in an industrial setting in this sort of study.

How long will such a study have to be carried out? A relatively harmless sort of cohort study is currently commonly arranged in various dietary manipulations expected to influence ischaemic heart disease.

## Conclusion

Epidemiology may be defined as the study of the distribution and determinants of disease in populations. Diseases of occupational origin fit into this definition.

A diagnosis of work-related problems depends strongly on a good medical and occupational history taken by an observant physician. Non-occupational factors such as smoking and alcohol consumption must always be considered.

The occupational physician wishing to conduct sound epidemiological studies must be a competent clinician.


## Résumé

L'epidémiologie est définie comme étant l'étude de la répartition et des facteurs déterminants des maladies parmi les diverses populations. Elle peut également s'appliquer à l'étude des maladies d'origine professionnelle. On traite des domaines présentant des problèmes communs et on donne des exemples destinés à illustrer la mortalité proportionnelle, la répression des cas de maladie et les études de générations.

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# Cashier Workstation Ergonomics

**Summary**

*Efficient and effective work performance of cashiers is dependent upon sound ergonomic design of the workstation. Such design requires an intimate understanding of the work procedures to be performed. Ergonomic principles related to cashier workstations are discussed as well as an evaluation of some commonly used models.*

Techniques of 'checking thru' grocery items in supermarkets have changed appreciably in the last few years. In the past, a cashier would either be provided with an assistant who bagged the groceries or all the items would be 'rung-in' and then bagged. More recent methods require the customers to bag their own groceries or the cashier puts the items in a bag as they are 'rung-in' ('Ring and Bag'). Many stores are using sophisticated label scanning devices to reduce the number of prices that must be manually keyed into the register. In many instances these new methods have been incorporated into a conventional cashier workstation with only minor workstation modifications. The introduction of these new techniques has been accompanied by increases in reported health complaints.

## Health Effects

The work task of a cashier involves many repetitious movements combined with prolonged static muscular contractions in numerous body parts. A recent Canadian study[1] reported that cashiers using scanning checkouts may handle from 450-600 items per hour, process 50-60 customers and fill 50-80 bags per hour. Questionnaire responses indicated that 66.2 per cent of the cashiers experienced general fatigue and 14.9 per cent reported remarkable fatigue. Sixty-two per cent reported feeling extremely fatigued under certain conditions such as working an entire day on the express checkout or working an entire Saturday. Fatigue appears to be one of the underlying causes of many of the symptoms experienced by cashiers. Loss of appetite, headache, insomnia, depression, irritability, anger and nervousness are common characteristics of chronic fatigue.[2]

Specific musculo-skeletal disorders are also experienced by cashier operators. As an occupational group, cashiers have a higher frequency of dullness and pain of the shoulder, arm, neck, wrist, hand and fingers.[3] The symptoms of the neck, shoulders and upper arms are classified as cervico-brachial disorders,

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while the wrist and hand symptoms are typical examples of tendonitis injuries. The cervico-brachial symptoms occur most commonly to the right side of the body. Most cash registers are operated with the right hand, and it is believed that the prolonged static contraction of the arm and shoulder muscles to raise the hand to the keys is a prime contributor to the cervico-brachial disorders. Highly repetitive movements with the hand and wrist out of their natural alignment may be responsible for the tendonitis injuries.

Cashiers also have reported complaints of symptoms in the lower extremities and the back.[1] A prolonged standing posture appears to be responsible for the problems with the legs, while the back symptoms are likely the result of leaning forward, twisting, turning and bending over.

Lastly, cashiers frequently report symptoms of visual fatigue and headaches later on in the workday. Principal contributors to these symptoms include poor lighting, glare, poor labelling and the layout of the cash desk.

## Ergonomic Principles for Cashier Workstations

The design of the workplace and the work task greatly influences the physical and psychological well-being of working individuals. Also, adverse health effects can be reduced and/or eliminated through the proper application of ergonomic principles.

### I) Work Surface Height

The work task of a cashier involves a high number of repetitions of a few specific movements. They are usually done for an extended period of time before a break is taken, and often are performed for an eight-hour workday. Improper design of checkstands can accelerate the fatigue associated with this work task and thus predispose the worker to specific health problems. One of the major design considerations involves work surface height. This includes such items as height of the conveyor belt, cash register keys, weigh scale and bagging surface. Ideally, the hands should be working at or just below elbow height with the upper arms hanging relaxed. This reduces the muscular effort required to keep the hands in a functional position. A dramatic reduction in the amount of fatigue in the shoulders and upper arms can occur by designing work surfaces to the proper height. This is not always an easy prospect if more than one person uses a checkout or if there are extreme variations in the physical size of

cashiers. Also a number of actions are required by the work task, and physical space limitations may make it difficult to locate all equipment at optimum height.

Sometimes, compromises must be made to overcome these difficulties. Any compromise should be made systematically and with consideration for anthropometric information about the employee population and knowledge of the frequency of repetition of different work actions. An example of a frequent action in many stores is keying in prices. Thus it is important that the keyboard be at the proper height; however, the height of the cash drawer, which is not accessed as frequently, may not be as critical. Many cash registers have the keyboard designed into the unit and this makes adjustment more difficult. If the keyboard is a separate unit connected by a cable to the cash register, as in many word processing units, it is easier to adjust the height to suit the individual.

### II) Forward Reach

A second important design criterion is that the distance of forward arm reach should be minimized. In a normal working population, repeated forward reaching should not exceed 40 cm (16 inches). The further that an object is away from the body the more difficult it is to lift. A relatively light object that is lifted at full arm extension can result in stress on the shoulder and spine. Also, an excessive forward reach requires bending at the waist, and this acts to increase the pressure on the spine.

### III) Twisting, Turning, Bending

Workspace layouts that require the operator to continually turn, twist or bend over should be avoided. The worker should be able to reach the conveyor belt, cash register keys, weigh scale, cash tray and bagging location without having to perform these manoeuvres. If compromises must be made, then the tasks performed least frequently should be the ones requiring turning, twisting or bending. Actions that combine twisting and lifting act to increase the risk of injury and should be avoided at all times.

## IV) Seated Work Posture

The majority of studies agree that a cashier involved in 'ringing in' prices functions best when seated. Standing in an upright posture requires more static muscular effort than sitting, and therefore is more tiring. One exception to the seated position being preferable is when heavy objects must be lifted. A standing position makes lifting easier because the legs can assist in the lift. 'Ring and Bag' style work procedures may not be conducive to seated postures since lifting the filled bags may be difficult from a seated position. This situation requires more investigation. The work surface height, forward reach and movement principles outlined earlier are especially important in checkout stands with a seated operator since the cashier has less manoeuvrability. The seat should be designed so that it is adjustable for height, provides lumbar support and incorporates the other features that allow comfortable prolonged sitting.[4]

One feature of a seated checkout stand design is that it may be more compatible for use by individuals of different body sizes. If work surface heights are established correctly in relation to each other then proper adjustment of the seat should place the cashier in an acceptable working position. The use of a seat requires that a footrest be provided so that the legs of shorter individuals are supported rather than left dangling above the floor. Excessive pressure should not be placed on the backs of the legs. Also, the workstation should be designed to allow the cashier to occasionally assume a standing posture.

## V) Vision

Vision problems can result from poor workstation design. Work areas should have sufficient light to allow easy reading of the items. Flicker-free diffused light of at least 1000 lux intensity has been recommended.[2] Displays and readouts should be located so that they are not subject to glare from natural or artificial sources. Prices should be clearly printed in large numbers with sufficient contrast to be read easily. One set of guidelines for checkout design suggests that the visual distance between the cashier and the work area should not exceed 80 cm, and normal distance between cashier and price tag should not exceed 33 cm.[2]

## Evaluation of Various Cashier Workstations

Cashier workstations should be evaluated using ergonomic design criteria. Three types of checkout stations commonly used in Ontario food stores are: 'Ring and Bag', 'Multiple-Chute' and 'Buggy to Buggy'. The 'front end' of the first two stations is often similar.

### 'Ring and Bag' and 'Multiple Chute'

With these designs the items are placed on a conveyor belt by the customer and are automatically moved towards the cashier for processing. The conveyor belt is generally located at a reasonable height for both the customer and cashier. However, the height of the cash register keyboard and weigh scale is frequently too high for many cashiers.

As each grocery item is processed, the customer is provided with price information on a visual display. This display should be positioned so that it can be seen easily by the customer. At checkout stations where the customer bags the groceries, the display should face the bagging area to encourage customers to begin bagging as the items are being checked through. This means that the display must be in a different position from that at the 'Ring and Bag' stations. The price information is also put on a paper tape and on a visual display at the front of the cash register. Many cashiers have difficulty reading the register display. At some stations the plexiglass holders for supplementary price information (e.g. specials or produce) partially obscure the register display, and glare at certain times of the day make the display difficult to read. The overhead lighting and large windows at the front of the store contribute to the problem. Glare also makes it very difficult to read the price of grocery items packaged in reflective material. Although glare is difficult to eliminate, antiglare filters on the displays may be useful.

The cash register keyboard is too high for many cashiers. The high profile of the register combined with the height of the register stand forces some cashiers to bend the hand upward at the wrist when keying in prices. Repeated keying movements with the hand out of alignment with the lower arm, in either the vertical or horizontal plane, may result in health problems. The keyboard height should be approximately 102 cm above the floor, allowing cashiers to adopt a better hand position for keying. Lowering the register may make the visual display somewhat more difficult to read, but this action is performed less frequently than the 'keying-in' of prices.

The cash registers are often aligned parallel to the conveyor rather than directly facing the cashier. With the cashier facing towards the conveyor, the right hand must be turned outward when keying. Again, repeated actions with the hand and lower arm out of alignment may lead to wrist and hand complaints. Changing the position of the cash register on the stand by rotating it counterclockwise 20 to 40 degrees may help to alleviate hand and wrist problems. This also puts the register display in a better position to be read by the cashier. The register should also be moved as close to the conveyor as possible to minimize the side arm reach when checking grocery items. A separate keyboard, which can be positioned independently of the register, makes these adjustments easier.

The position and height of the weigh scale forces many cashiers to stretch or stand on their toes when weighing produce. Ideally, the scale should be positioned much closer to the register and conveyor. With some existing checkout station designs, the weigh scale could be positioned directly over the lowered cash register. Also, a low profile (thin) weigh scale makes for easier placement at a lower height.

Cashiers at the 'Ring and Bag' stations stand during their shift. Operators at the 'Multiple-Chute' stations sometimes have the option of sitting or standing. However, the seated posture is not of benefit at some workstations. For example, where there is not adequate leg clearance under the register stand, the operator is forced to sit back from the cash register. As a result, the arm reach to the conveyor and weigh scale is excessive. Consequently, the cashiers lean forward on the seat, and thus are not able to take advantage of the back support. Also, some seats lack the essential characteristics of an effective seated position.[4] In many locations, lower profile cash registers and new workstands would have to be installed to make a prolonged seated option viable. While a properly designed seated work position is preferable, thick rubber floor mats help reduce the physiological stress of prolonged standing.

## 'Buggy to Buggy'

Recently, another approach to cashier checkout station design has been taken by some stores. In this design, a customer's buggy and an empty buggy are placed end-to-end at the left side of a cashier's booth. The cashier lifts each item from the customer's cart with the left hand and places it in the empty buggy while the right

hand reaches up to the keyboard to ring in the price.

The cashier's booth is sometimes raised above floor height and this significantly increases the distance of arm reach required when lifting items from buggy to buggy. The excessive arm reach requirement forces cashiers to bend at the waist while twisting to lean outside the booth to reach the groceries. In addition to this, a considerable amount of muscular exertion is required to support and lift the torso of the cashier as the work is performed. To perform the work task the cashier is forced to sit on the front corner of the chair (not using the backrest) and extend one leg for stability. The workstand also has the cash register keys too high, which results in the problems described earlier. This awkward posture must be maintained while processing a customer's order.

The 'Buggy to Buggy' checkout stations make it very difficult to follow sound ergonomic work practices. The height of the bottom of the buggies and the bending that results forces individuals to assume awkward postures for extended periods of time. Excessive muscular fatigue can occur and may lead to health complaints.

## Conclusion

Cashiers can experience specific health problems related to the design of the checkout workstation. The fatigue resulting from poor design is manifested as specific musculo-skeletal problems and also in more general symptoms such as headaches, sleeplessness and irritability.

Work surface height should be kept at, or just below, elbow height when the arms are hanging relaxed at the side. Forward reaches should be kept to a minimum. Equipment should be arranged so that turning, twisting and bending are minimized. Seated operators appear to have less difficulty than standing cashiers when the checkout is designed properly and heavy objects do not have to be lifted. The workstation must have sufficient lighting, and sources of glare should be eliminated.


## Résumé

Le rendement et l'efficacité du travail accompli par les caissiers (caissières) dépend de la conception judicieuse des postes de travail sur le plan ergonomique. La configuration de ces postes exige la compréhension parfaite des mécanismes du travail que s'y accomplit. On traite des principes ergonomiques ayant trait aux postes de caissiers (caissières) et de l'évaluation de certains modèles courants.

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# Guidelines for Examining Physicians on Surveillance of Isocyanate-Exposed Workers

**Purpose of Medical Surveillance**

1. To detect occupational asthma caused by sensitization to isocyanates.

2. To identify workers who may be developing chronic airflow limitation due to isocyanate exposure.

3. To provide a baseline of data to which future health changes from isocyanate exposure may be compared.

**Risk Group**

Workers exposed to organic isocyanates (TDI, MDI, HDI, IPDI, etc.).

**Known or Suspected Respiratory Sequelae**

All workers who are exposed to high concentrations of isocyanates may develop irritation of the respiratory mucous membranes, which can cause a syndrome resembling acute bronchitis. About five per cent of workers may develop sensitization, manifested as asthma, but the lower limit of isocyanate concentration or duration of exposure to prevent its development is unknown. Likewise, the role of previous medical problems or genetic background that may predispose individuals to sensitization is also unknown. Isocyanate *sensitization* may produce a *late* asthmatic reaction recognized by nocturnal wheezing and dyspnoea, often recurring for several evenings or nights, even after the source of the isocyanate exposure at work has been removed. *Early and dual* asthmatic reactions may also occur. The development of *chronic airflow limitation* related solely to isocyanate exposure has been suggested, but its existence and any predisposing factors have not been established with certainty. One study[1] of polyurethane-foam production workers exposed to average TDI levels in excess of 0.0035 ppm showed an accelerated mean decline of 119 ml in forced expiratory volume in one second ($FEV_1$) over a four-year period, with most of the change occurring in the first two years. This was not explained by age, sex, smoking history or atopy, and the group did not include asthmatics. The accelerated decline in $FEV_1$ roughly equals that seen in cigarette smokers. Finally, a few

workers have been found with *hypersensitivity pneumonitis*, recognized either by transient or permanent pulmonary infiltrates on the chest X-ray or by a persistent decline in forced vital capacity (FVC).

**Pre-Placement Examination**

1. Medical history, with emphasis on relevant family history, past occupational exposure, smoking history and past or current respiratory problems, including asthma and allergies. A questionnaire emphasizing respiratory and, especially, asthmatic symptoms is appropriate at this time.

2. Physical examination, with special attention to the respiratory system and skin when indicated by the history and responses to the questionnaire.

3. Forced expiratory spirometry, done to quality standards equivalent to at least those recommended by the American Thoracic Society, is essential to obtain a baseline reference.

4. Chest X-rays and more detailed pulmonary function tests, e.g. a histamine or methacholine inhalation test, if indicated by findings from the above examinations.

**Pre-Employment Risk Factors**

No pre-existing risk factors have been correlated with the development of isocyanate sensitization. At the present time it is prudent to consider current asthma to be a contra-indication to employment in isocyanate exposure although the scientific backing for this view is lacking.

**Screening During Employment**

A questionnaire with emphasis on respiratory symptoms and asthma shall be administered every six months. In the absence of a validated asthma questionnaire, a set of questions relating to respiratory symptoms should be asked. If sensitization or occupational asthma is suspected from this, the worker should be referred for diagnostic investigation and follow-up. Forced expiratory spirometry shall be undertaken at two-yearly intervals at least, preferably on the first day of the work-week. The tests may be repeated with advantage during the shift.

**Action Levels During Employment**

1. The onset of new symptoms declared on the questionnaire should lead to further investigation.

2. A confirmed greater than 15-20 per cent decline in $FEV_1$ from previous values is suggestive evidence for a diagnostic follow-up.

3. Workers with pre-existing moderate to severe pulmonary function impairment should not be assigned to work where spills may occur.

4. If isocyanate sensitization is suspected, the worker should be referred for further investigation, and it should not be assumed that his respiratory symptoms are due to work exposure until this has been substantiated.

**Removal From Work**

If removal from work is to be recommended, the chest physicians of the Ministry of Labour and the Workers' Compensation Board (WCB) should be informed. This will permit an accelerated claim procedure to be started.

**Reference**

[1]Wegman DH, Peters JM, Pagnotto LJ. Chronic pulmonary function loss from exposure to TDI. Brit J Ind Med 1977; 34: 196-200.

# Publications Available From the Government Book Store

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# News and Notes

## Conference on Medical Screening and Biological Monitoring for the Effects of Exposure in the Workplace

**Organized by NIOSH, the National Cancer Institute (NCI) and the EPA, and held in Cincinnati, Ohio, on July 10-13, 1984.**

**Abstract**
The first national U.S. conference on medical screening and biological monitoring for the effects of exposure in the workplace addressed the current situation and the issues involved in biological monitoring and medical surveillance of exposed workers. Screening presents many difficult issues such as test validation, methodological problems and ethical and legal concerns. However, the conclusion reached at the conference was that screening is necessary for several reasons, including early detection of disease, secondary prevention of disease, the host factor, determination of the internal dose and the inadequacy of hygiene and air monitoring alone.

The conference was organized into parallel sessions, which prevented anyone from attending more than half of the presentations. The proceedings will be published, however, so that full appreciation of the topics covered may be obtained.

In recent years toxic exposures in the workplace have increasingly received the attention of the public. The chief remedies are primary prevention, i.e. preventing worker exposure, and secondary prevention, i.e. monitoring the worker by a medical screening program.

Medical screening may be defined as the examination of workers for pathological conditions, whereas biological monitoring is the examination of workers for the presence of an intoxicant or its metabolite. Although the utility of medical screening and biological monitoring may appear obvious, in the U.S. (and also in Canada) there is, at present, controversy regarding the scope and content of such programs.

The purpose of the Cincinnati conference, which was the first national U.S. conference on medical screening and biological monitoring, was to assess the present situation and to discuss the controversial issues. The conference was important because it was regarded as a beginning from which it is hoped will come, in future, a national U.S. policy on medical screening and biological monitoring, which is, at present, lacking.

Up until now each OSHA rule on toxic substances

has contained different directives for medical screening and biological monitoring, and no coherent policy is apparent. A national U.S. policy on medical screening and biological monitoring will affect Canada and Ontario due to the existence of multinational corporations and Canada-U.S. trade links.

The prevalence of medical screening programs in the U.S. has been documented by the National Occupational Hazard Survey. In 1972 a stratified sample of 5,000 private industries was selected by NIOSH and the prevalence of medical screening was ascertained in this sample. In that year 38 per cent of workers were required to take preplacement examinations and 14 per cent were offered periodic examinations. In the past few years this study has been updated, and, in the U.S., at present, 49 per cent of workers receive preplacement examinations and 30 per cent receive periodic examinations. The study has found that plant size, type of industry and the presence of a union are important determinants of screening.

In regard to the type of industry, the study found, for example, that 96 per cent of workers exposed to beryllium in the electronics industry are screened. However, only 74 per cent of lead-exposed workers and 45 per cent of arsenic-exposed workers are screened. This is in spite of the OSHA lead standard. Interestingly, the update found that record-keeping of causes of illness or absenteeism has actually declined in the last 10 years. The causes of this decline are speculative.

## Factors to be Considered in Medical Surveillance and Biological Monitoring Programs

### 1. Methodology

Although the prevalence of medical screening and biological monitoring has increased in the past 10 years, the goals and principles of many such programs remain to be established. The conference organizers suggested that the principles used for community screening and public health be modified to make them more appropriate for the workplace. Thirteen precepts of screening were identified as starting points for the conference discussion:

1) The disease to be prevented should be important.

2) The disease need not be treatable, but must be preventable.

3) Follow-up care should be planned for participants of screening programs.

4) The condition sought must have a recognizable latent or early symptomatic stage.

5) The screening test need not be uncomplicated or inexpensive.

6) Professionals who utilize the tests must be skilled in their interpretation.

7) Screening tests should be targetted to specific job risks.

8) The timing of tests should be determined by the natural history of the disease.

9) The test should be effective.

10) Normal values for screening test results for the work force should not be assumed to be equivalent to the values in the community.

11) Action levels for tests results should be decided upon before the commencement of the screening program.

12) The program should be acceptable to the work force.

13) The goals of the screening program, whether they are identification of individuals for treatment or for more primary preventative measures such as environmental monitoring, should be specified.

Obviously, much remains to be done before all these principles will be fulfilled in every occupational medical screening program. The conference highlighted the complexities involved in formulating appropriate medical surveillance and biological monitoring programs. The tests or biological monitoring must be valid and reproducible, and, ideally, should be capable of measuring toxicity and not just exposure.

If the results of biological monitoring are to be used solely to document exposure, then it follows that the test must be as specific as possible, i.e. without confounding factors.

The natural history of the disease has a bearing on the medical surveillance and biological monitoring program. If the latency of a particular cancer is 15 to 20 years, then it may not be justifiable to perform yearly chest X-rays in a worker cohort that has just recently been exposed to the agent.

If the disease is untreatable, even when it is first detected, this, also, has a bearing on the program. Tests that are capable of detecting the disease at an earlier, treatable or reversible stage must then be identified if the program is to fulfil the goal of secondary disease prevention.

All the possible goals of medical screening and biological monitoring must also be considered. If the goal of the program is not only to monitor exposure and toxicity of a particular agent but also to screen workers for their general health and fitness for exposure, then the medical surveillance program must be broad and must include a general history, physical examination and appropriate clinical tests. Another possible goal is the use of program results to improve the working environment, i.e. to improve primary prevention. The ethics of occupational health require that the aim of tests should be to protect not only the entire work force but also the individual worker.

Action levels, including possible worker removal, must be specified ahead of time and must be agreeable to both management and labour. Otherwise, the program will generate data that may not be used. Obviously, to fulfil all these possible goals, programs must be subject to periodic review. If necessary, tests that are not found to fulfil the criteria must be discarded. New clinical tests are constantly being developed as there is better basic understanding of metabolism and the mechanism of action of xenobiotics. Normal levels may be adjusted with better epidemiological and workplace surveys and improved analytic techniques. The maintenance of good programs will require periodic updating, and keeping up with current advances in biology.

There are some methodological difficulties associated with screening tests used in medical surveillance programs. Some tests, such as pulmonary function tests, are widely used, yet may not have established predictive values.

When used for early detection of disease, screening tests may permit detection prior to the point of incurability. While, ideally, one would wish to pick up work-related disease in its pre-clinical stages, the point at which this stage is reached is difficult to identify in

many cases. Another methodological difficulty associated with screening tests is the difficulty of determining a test's true sensitivity.

## 2. Ethical

In addition to the methodological problems, ethical concerns are increasingly being raised in regard to medical screening and biological monitoring. There are many proponents of the right of a worker to refuse biological monitoring and medical surveillance. Without protection of worker confidentiality there is the danger that the communication of test results to persons in authority may be disadvantageous to a worker. There is some legal opinion that the laws do not, at present, provide protection against the use of medical screening for discriminatory purposes.

For example, test results may be used to exclude the sensitive worker or the worker with certain medical conditions, even when such conditions may not affect that worker's ability to do his or her job. The conference attendees acknowledged that workers enter the workplace with different inherent degrees of risks to workplace hazards. If the employer has no knowledge of employees' medical conditions, he or she cannot be expected to take action to accommodate workers at greater risk.

As yet, genetic tests have not been routinely applied in the workplace. However, if such tests, and others such as allergenic testing for the sensitive worker, can be validated, they may be used more commonly. Any proposed genetic tests must be subject to strict criteria before use. There is an untested legal opinion that the genetically susceptible worker may be covered under legislation for the handicapped.

It was suggested that mandatory participation of workers in medical surveillance programs may be justified if:

1) workers' economic interests are protected;

2) research interests to which workers have agreed in principle would be subverted by non-participation;

3) workers are provided with information generated by the medical surveillance program.

## 3. Legal

Along with the ethical issues there are also many legal issues involved with medical screening and biological monitoring. The connection between the workplace hazard and worker disease may be established by epidemiological or physiological evidence, and screening results may provide data for future disease claimants. Conversely, the employer may also use data from screening procedures to refute claims of causation.

There is only an incentive for employers to perform biological monitoring if it is assumed that employer liability will be reduced. Included in this cost-effectiveness approach is the cost of the tests, record keeping, etc. The liability of the employer is also determined by the extent to which, in different jurisdictions, the burden of proof of disease rests on the employee.

Thus, results of medical screening and biological monitoring may be central to compensation cases. The establishment of disability is hampered by the fact that there are no established guidelines for management of work incapacity or the quantification of work incapacity. At present, there is, due to the inadequacy of the compensation laws in some jurisdictions, a tendency for workers to bring 'toxic tort' suits. Such suits have been against primary manufacturers and suppliers rather then against employers. The recent dioxin settlement is an example of this. There is also the possibility that, in order to avoid liability, primary producers may withdraw from the manufacture of certain agents that are associated with significant risk, even when these are profitable operations. As illustrations there are the examples of asbestos and, more recently, ethylene glycol ethers.

A related issue is the concealment of risk. Assuming that a serious work-related hazard has been identified by medical screening and biological monitoring, the manner in which the employer should notify employees of risk is at issue. In recent studies conducted by NIOSH on high-risk workers, the workers so identified were informed of their status. Medical screening is now being carried out on these cohorts. In private industry, the role of the occupational physician is especially delicate since, in his relationship with the worker, the physician has a role in between that of an independent medical practitioner and an employee of the company. The alleged failure to communicate known risk to workers has been used in decisions against, for example, asbestos employers.

Medical removal is another associated ethical and legal question. Action levels specified by regulatory agencies may specify only reviews of hygiene practices and improvement in working conditions on the basis of screening tests rather than removal for medical reasons. Conversely, some regulations and some private employers remove workers on the basis of medical screening and biological monitoring test results. In Ontario, workers who have been removed for medical reasons, under the Lead Regulation for example, have received compensation. However, in other jurisdictions, such as OSHA, there have been recent decisions that would make the removal problematic, i.e. the courts have now stated that the protection of workers' wages after such removal is not OSHA's function.

**Need for Medical Screening and Biological Monitoring**

Despite the fact that the screening may open up a Pandora's box of follow-up, record-keeping, possible litigation, etc., the conference participants concluded that medical screening and biological monitoring were necessary. This was chiefly due to the multiple interacting causes of work-related disease. The host or worker factor and the behaviour factor cannot be ignored even if environmental factors are controlled, and some form of medical surveillance will always be needed. It is advantageous both for individuals and for cohorts of workers to measure the internal dose of toxic substances as well as the external concentration. As we become more sophisticated, the internal dose may mean the amount of chemical recently absorbed, the amount of chemical stored in the organism or the amount of chemical bound to critical sites in the target organ.

As an example of the use of biological monitoring in conjunction with environmental monitoring, a prominent haematologist speaking at the conference spoke of the use of automated blood lymphocyte counts, which could pick up the 'benzene effect' in groups of exposed workers. The important point made by the haematologist is that such an effect may be missed by measurement of air concentrations.

**New Developments in Medical Screening and Biological Monitoring**

New research findings in the field of medical screening and biological monitoring was one aspect covered at the conference. Many of these developments are possible through advances in basic science. There is an interagency agreement between the U.S. NCI and NIOSH to investigate workplace carcinogens. For

example, a chemoprevention intervention study is ongoing in which the relationship between the intake of beta-carotene or 13-cis-retinoic acid is being investigated in asbestos workers.

The ACGIH, with help from NIOSH, now has a program of developing 'BEIs' or biological exposure indices. These are urine or blood values for toxicants that are correlated with ACGIH TLVs and accompanied ACGIH documentation. The 1984-85 ACGIH booklet contains BEIs for six substances: carbon monoxide, ethylbenzene, styrene, toluene, the xylenes and trichloroethylene. These BEIs are subject to all the possible pitfalls of such values, such as being a measure of exposure and perhaps not of toxicity, the problem of the correction of urinary samples to a standard specific gravity or creatinine level, and intra- and inter-individual variations.

There are new methods under development for the detection of neurotoxity. Industrial toxins such as lead and many other substances may cause symmetrical polyneuropathies, and a new testing device is under development that can measure associated decreased pain and temperature sensation. Another screening test that holds future promise is based on various types of evoked potentials, i.e. auditory/brain stem, visual or somatosensory evoked potentials.

For the screening of colorectal cancer, flexible sigmoidoscopy is the most sensitive test, but in the workplace it may not be more acceptable than serial hemoccult testing for primary screening.

For lung cancer, the most promising test for the future appears to be radio- or drug-tagged monoclonal antibody assays. Assays are also being developed for benzo(a)pyrene-DNA adducts in lung cancer patients, and studies are now ongoing in cigarette smokers and coke-oven workers. At present, while four-monthly chest X-ray and sputum cytology may detect causes of lung cancer earlier, overall yearly mortality is unchanged.

Breath analysis was stated to be not yet suitable for use as a routine screening method due to the need for further standardization.

An X-ray fluorescence method is capable of measuring the body burden of heavy metals such as lead and mercury. The test has the disadvantage of requiring expensive and not-portable instrumentation, and a small dose of radiation (30-40mR) must be administered during the test.

The situation in regard to dermatologic screening to detect sensitive workers is complex. While it was stated

by a dermatologist at the conference that 85 per cent of workers who are affected by contact dermatitis are atopic individuals, the situation in regard to atopic individuals and sensitization is unclear. Atopic status has not been found to be a risk factor for TDI and wood dust workers, but it is a risk factor for grain handlers and some other categories of occupationally-exposed workers.

Advances are being made in the study of male germ cell toxins. Sperm assays have the advantage of large numbers of test organisms and the fact that the individual who is exposed to a mutagen can himself be studied rather than his progeny.

An individual's sperm morphological pattern appears to be quite consistent over time, and concentration is the main intra-individual variation. Studies that are designed longitudinally, i.e. the multiple sampling of a few donors, have statistical advantages over cross-sectional study designs.

In regard to bladder cancer, although the population that was exposed to benzidine and beta-naphthylamine based dyes is aging, there are approximately 20 new occupations that may carry increased risk of bladder cancer, such as hairdressing, industrial photography workers, etc. Promoters for bladder cancer are recurrent bladder infections, use of the chemotherapeutic agent cyclophosamide, cigarette smoking and the human papilloma virus. The detection of antibodies to human papilloma virus may be a suitable screening test.

## Conclusion

The conference was a forum for frank discussion of many controversial issues in the field of medical screening and biological monitoring, and the quality of the speakers was impressive. The conference confirmed that it is worthwhile to bring together experts in this field, and it is to be hoped that further advances will result from the continued efforts of a task force that has been set up as a result of this conference.

*Marie Roy*

**Résumé**

La première conférence nationale organisée aux Etats-Unis sur le dépistage médical et le contrôle biologique des effets de l'exposition aux substances dangereuses sur le lieu de travail s'est penchée sur la situation actuelle et a abordé les questions relatives au contrôle biologique et à la surveillance médicale des ouvriers soumis aux expositions. Le dépistage pose de nombreuses et difficiles questions, telles que la validation des tests, les problèmes méthodologiques et les responsabilités déontologiques et légales. Toutefois, la conclusion qui a été tirée de cette conférence est que le dépistage est nécessaire pour plusieurs raisons, y compris la détection précoce de la maladie, sa prévention secondaire, le problème du porteur, l'estimation de la dose interne et surtout la médiocrité de l'hygiène et du contrôle de la qualité de l'air.

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When submitting your manuscript please follow the instructions to contributors on the title page of this issue.

# Coming Events

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| January 21-25, 1985 | International Symposium on Air Pollution Abatement by Filtration and Related Methods, World Health Organization Conference Facility in Copenhagen. |
| March 4-6, 1985 | Back Injury in The Workplace '85: Strategies for Prevention, Westin Hotel, Toronto, Ontario, Canada. |
| April 16-19, 1985 | International Symposium on Occupational Exposure Limits. WHO Europe Headquarters, Copenhagen, Denmark. |
| April 29 - May 2, 1985 | International Symposium on Biological Monitoring of Exposure to Metals and Inorganic Compounds. In conjunction with the 189th ACS National Meeting. Call for papers: contact Dr. H.K. Dillon, Southern Research Institute, 2000 Ninth Avenue, South, P.O. Box 55305, Birmingham, AL 35255-5305<br>Miami Beach, Florida. |
| May 6-8, 1985 | Fourth International Symposium on Hand-Arm Vibration under the auspices of the Scientific Committee on Health Effects of Physical Environmental Factors of the Permanent Commission and International Association on Occupational Health, Hanassaari Cultural Centre, Helsinki, Finland. |
| May 8-10, 1985 | International Colloquium on Safety at Work with Automation and New Technologies, Bonn and Hennef/Sieg, West Germany. |
| May 19-24, 1985 | American Industrial Hygiene Conference, Las Vegas, Nevada. |
| June 3-5, 1985 | Noise-Con 85: Computers for Noise Control, Columbus, Ohio. |
| August 18-24, 1985 | Health Care Expo '85, Washington, D.C. |
| September 23-25, 1985 | Radioactive Waste Management, Winnipeg, Manitoba, Canada. |

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| September 26-27, 1985 | Information Meeting, Canadian Nuclear Fuel Waste Management Research Program, Winnipeg, Manitoba, Canada. |
| October 1-3, 1985 | Ventilation '85, 1st International Symposium on Ventilation for Contaminant Control, Royal York Hotel, Toronto, Canada. For details contact Dr. H.D. Goodfellow, Hatch Associates Ltd., 21 St. Clair Ave. East, Toronto, Ontario, Canada M4T 1L9. |

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